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Evaluating garments in augmented reality when shopping online

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Abstract

Purpose

Augmented Reality (AR) integrates computer-generated images to a physical environment in real-time. Online apparel shopping presents some product-related risks, as consumers can neither physically see and touch the products nor try them on. The present study examined whether AR conveys reliable apparel product information in terms of fit, size, and product performance; and how AR affects attitudes toward apparel and purchase intentions when shopping online.

Design/methodology/approach

This research was designed as a within-subject quasi-experimental study using repeated measures in two conditions: virtual try-on using the AR technology vs. physical try-on. A scenario was developed to help participants imagine themselves shopping online for a specific dress.

Findings

Results indicated that size and color of dresses were conveyed accurately when utilizing AR as compared to physical try-on. Visual attributes such as style, garment details, and coordination with other items were found to be satisfactorily predicted when AR was employed. Overall, attitudes towards both AR and real dress, and purchase intentions were favorable. Participants with higher telepresence levels were found to have more positive attitudes towards the dress and greater purchase intentions when using AR as compared to the participants with low telepresence levels.

Research limitations/implications

Our findings implied that AR can provide enough information especially for garment sizes and visual characteristics when making purchase decisions. AR technology can be instrumental in introducing a certain style, building positive attitudes towards products, and driving sales, when the consumers perceive a certain level of “being there”. This study was limited to female students in North America. Also, because a single stimulus was used, the results cannot be generalized to other stimuli.

Originality/value

Our study findings showed that participants were able to select the right garment size by using AR. The average ratings for visual characteristics such as style and detail were above the neutral level when using AR; indicating that participants can understand visual attributes in AR when shopping online. Moreover, in the AR condition participants with higher telepresence levels had higher attitudes towards the garment and purchase intentions as compared to the participants with low telepresence. AR can be instrumental for online apparel shopping. Retailers need to understand the potentials of these technologies and work with technology developers to enhance consumers' experiences.

Keywords

Augmented reality, Apparel, Product performance, Virtual, Fit and size, The stimulus-organism-response model

Disciplines

Communication Technology and New Media | Community-Based Research | Fiber, Textile, and Weaving Arts | Industrial and Product Design | Public Relations and Advertising

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Evaluating garments in Augmented Reality when shopping online

Introduction

According to a recent report (Narvar, 2017), online shoppers returned apparel more than goods from any category (43%); 70% of apparel is returned due to being the wrong size or color. In online shopping environments, simulated reality enables consumers to "test drive" products during the pre-purchase stage and decreases product returns (Edvardsson *et al.,* 2005). Especially in fashion, such simulation systems provide companies substantial opportunities by compensating for the lack of experiential shopping through enriching product information with interactive visual cues (Fiore and Jin, 2003).

Image interactive technologies (IIT) are website features designed to simulate actual product experiences by enabling online shoppers to (a) view products from different angles; (b) change design features; and (c) see how apparel products look on their bodies/avatars to understand garment fit and appearance (Fiore and Jin, 2003; Fiore *et al.*, 2005; Merle *et al.*, 2012). IIT creates a feeling of presence in online environments, fully immersing shoppers in the environment and enabling interaction. Immersion in an online environment is an important aspect that generates a psychological condition, which is necessary for experiencing presence when there are only visual clues for making purchase decisions (Steuer, 1992; Witmer and Singer, 1998).

For online apparel shopping, there are two distinct IIT approaches for virtually trying garments. One approach requires customizing virtual avatars from an existing library of parametric models to represent shoppers' body measurements and shapes as closely as possible, then trying digital garments on these avatars. Physical and mechanical properties of garments can be modeled three-dimensionally (3D), allowing shoppers to view garments in transparent or tension modes and visually judge where the garment is tight or loose (triMirror, n.d). 3D garments can be also generated from two-dimensional (2D) photographs for virtual try-on and size recommendations (Metail, n.d.). However, such environments with both virtual garments and virtual bodies can create artificial settings and make it difficult for consumers to make real-world connections to the product (Azuma, 1997). As Li *et al.* (2001) indicated, presenting products in their environmental context is important. Consumers prefer to see products within their intended context, such as “the ring displayed on a hand or the laptop computer presented in an office setting” (Li *et al.*, 2001, p. 28). Therefore, using Augmented Reality (AR) for virtual try-on is another approach gaining popularity when shopping online, as consumers can see garments or accessories on their bodies without spending time customizing avatars.

AR technology integrates computer-generated sensory information with a physical environment in real-time. Pine and Korn (2011) described AR as using digital information “to enhance, extend, edit, or amend the way we experience the real world” (p. 36). AR systems appear 3D and can apply to all senses (Azuma, 1997). In order to operate an AR application, users must have access to a display device with a video camera (e.g., smartphones, tablets, computers, or mirror-looking screens). On this display device, users can see their environment while computer-generated images of products are placed on top of the view in real-time (Carmigniani *et al.*, 2011). From this perspective, AR can provide shoppers with an experience that resembles physical interaction (Verhagen *et al.,* 2014) and can potentially compensate for the lack of experiential information in online settings (Kang, 2014; Lee, 2012), thus bridging the gap between online and offline shopping (Huang *et al.,* 2011; Lu and Smith, 2007).

Previously, researchers focused on the development, usability, and user acceptance of the AR technology (Chang *et al.*, 2013; Huang *et al.*, 2011; Kang, 2014; Lu and Smith, 2007; Rese *et al.*, 2017), AR's experiential value at the pre-purchase stage (Bulearca and Tamarjan, 2010; Huang and Liu, 2014; Kang, 2014), and AR's impact on purchase intentions (Beck and Crié, 2018; Huang and Liu, 2014; Rese *et al.*, 2017). However, no researcher, to our knowledge, has specifically developed a study to compare consumers' perceptions of using AR for evaluating garment sizes, fit, and product attributes when shopping online with their responses towards the physical garments once they were "ordered and received." Therefore, the purpose of the present study was to examine consumers' perceptions of a garment's size, fit, product performance, attitudes towards the product, and purchase intentions when using AR virtual try-on in an online shopping context as compared to when physically trying on the real garment. The focus of the present research was women. Specifically, we aimed to understand whether AR virtual try-on could provide a comparable representation of physically trying on a garment in terms of fit, size and product performance, and if there would be a difference between AR virtual try-on and physical try-on regarding their impact on attitudes towards the apparel product and purchase intentions.

Literature Review

A brief overview of AR apparel applications in online environments

In AR environments, apparel applications range from overlaying 2D static front images of garments on the real-time static image of the viewer's body (e.g., Webcam Social Shopper by Zugara) to 3D, which is simultaneous rendering or dynamic fitting of the garment around the viewer's body to simulate garment drape as the viewer moves (e.g., Magic Mirror). In both cases, AR imagery allows viewers to see immediately how clothes would look on them (Batista, 2013; Huang and Liu, 2014; Pachoulakis and Kapetanaki, 2012). The experience with an AR garment is very similar to holding a garment up to oneself in front of a mirror (Schwartz, 2011). AR applications in the apparel industry are usually developed for websites and mobile devices so that customers can virtually try on clothing and accessories (Carmigniani *et al.*, 2011; Pachoulakis and Kapetanaki, 2012). Zugara, FittingBox, MemoryMirror, and Magic Mirror are some of the developers that provide AR applications to fashion brands. In 2017, Gap collaborated with San Francisco-based start-up Avametric and launched a digital dressing room with AR, where shoppers can create their avatars and try garments on (Avametric, n.d.). In 2018, Amazon patented a magic mirror that uses AR to superimpose garment images to users' reflections in the mirror in real-time, which can help with an AR-enabled shopping experience on Amazon.com (Boyle, 2018).

Although only a few apparel retailers have experimented with AR in their online stores, more should consider using the potential of AR technologies to support consumers' online shopping (Pantano *et al.,* 2017). Benefits of using AR include (a) providing shoppers with digital help and increased likelihood of exploring more garments, (b) suggesting clothing based on user preferences or fashion trends, (c) reducing the number of returned items, and (d) low technology barriers (Chitrakorn, 2018). Challenges of using AR in online shopping are related to whether these tools can assist shoppers with understanding product performance when making purchase decisions (Pantano *et al.*, 2017).

Conceptual framework

To explore how consumer perception of apparel products and behavioral intentions would be impacted by AR in online apparel shopping, the Stimulus–Organism–Response (S–O–R) model (Mehrabian and Russell, 1974) was selected. The model proposes that environmental stimuli are associated with behavioral responses, and that environmental stimuli (S) affect organisms (O). Response (R) is the result of the internal (cognitive or emotional) process of the organism in the form of approach or avoidance behaviors (Eroglu et al., 2003; Fiore and Kim, 2007; Mehrabian and Russell, 1974; Prashar, Sai, and Parsad, 2017; Watson, Alexander, and Salavati, 2018). The S-O-R was applied by numerous researchers to understand the influence of new retail technologies on consumers' affective and behavioral responses when shopping online (Eroglu et al., 2001; Fiore and Kim, 2007; Prashar et al., 2017; Watson, et al., 2018; Wu et al., 2013) and is considered as a robust model (Watson et al., 2018). Past studies found that AR creates rich sensory experiences and influences mental imagery, resulting in positive emotional and behavioral responses (Park and Yoo, 2020; Watson et *al*., 2018). In the present study, the S-O-R model was used as a foundation to examine hypotheses. The hypotheses were developed based on the elements in the model: stimuli (i.e., AR and physical try-on), organism (i.e., telepresence as an internal state) and responses to the stimuli (i.e., attitudes towards the product and purchase intentions)

Understanding Stimulus: Perception of apparel products in online AR environments

There are only a few studies investigated how garments and fashion accessories would be perceived in online AR environments. In a study conducted by Chang *et al.* (2013), a real-time 3D dynamic fitting room was developed by using AR and Microsoft Kinect, through which sensors were used to automatically measure participants' sizes. Findings showed that sizes based on the Kinect measurements were close to participants' claimed sizes, indicating the potential of using AR for online apparel shopping. Verhagen *et al.* (2014) examined the differences among three different eyeglass presentation formats (picture, 360-spin application, and AR try-on) on the Ray-Ban website. They found that AR can make users feel significantly more "locally present" as compared to seeing pictures or 360-spin formats of the products, suggesting that retailers who sell products that consumers need to try on before buying can use AR technologies.

Online shoppers tend to perceive that products they see on a website may not look, feel, or fit the same as the products they find in a brick-and-mortar store (Yu *et al.*, 2012). For apparel products, these perceptions manifest themselves as risks related to product performance based on three main attributes: visual, tactile, and trial (Yu *et al.*, 2012). Therefore, it is important to measure whether apparel products received after using an AR application for online shopping are close to shoppers' expectations. Suh and Chang (2006) argued that online shopping environments lead to a discrepancy between online products (pre-purchase) and physical products (post-purchase) as consumers can not touch or try-on the online products. According to the authors, this would result in either finding physical products more satisfactory (i.e., positive disconfirmation), or the opposite (i.e., negative disconfirmation).

Previous AR studies examined size selections (Chang *et al.*, 2013), technology acceptance (Pantano *et al.*, 2017), telepresence (Verhagen *et al.*, 2014), interactivity and vividness (Yim *et al.*, 2017), and perceived tactile sensations (Overmars and Poels, 2015) in various AR settings. However, none of these studies specifically addressed if and how shoppers fit into the sizes selected by using an AR application, and if AR products' expected performance matches actual products' performance once the online order is received. Therefore, the present study's results would be beneficial for the researchers when examining AR in online shopping, and help retailers increase benefits and overcome challenges by providing them with experimental data. In light of these needs, the following hypothesis was examined:

H1**:** AR virtual try-on will provide a comparable representation of physical try-on in terms of (a) finding the right size, (b) evaluating fit, and (c) evaluating product performance.

Organism: Telepresence

Research on IIT-supported environments shows that shoppers can see digital product attributes through a variety of rich visual cues, using their gestures to control the environment (Huang and Lui, 2014; Merle *et al.*, 2012). Because of this increased interaction, products are experienced in “the mind’s eye,” which can potentially provide accurate sensory information (e.g., touch, taste, and smell) based on real-world experiences with similar products (Schlosser, 2003). Telepresence is defined as a consumer’s sense of being present in a virtual environment, such as an online store, where consumers could browse and shop as they would in a brick-and-mortar location (Mollen and Wilson, 2010; Shih, 1998). Lim and Ayyagari (2018) described it as “the perception of direct product experience simulated through a medium” (p.361). Telepresence provides a good basis to understand consumers’ immersion and information processing in the online AR context, as literature has found that telepresence is crucial for consumer immersion in virtual environments (Steuer, 1992). Sense of telepresence is created by the quality and quantity of simulated sensory information in the virtual space (Fiore *et al.*, 2005), particularly the perceived interactivity and virtuality, both characteristics that set AR apart from more traditional forms of online shopping (Javornik, 2016). Coming into contact with digital products in AR can enrich product experiences. Additionally, consumers perceive AR products as tangible and attractive (Verhagen *et al.*, 2014).

Response: Attitudes towards apparel products and purchase intentions

AR online shopping experiences can result in positive attitudes toward products and increased purchase intentions (Verhagen *et al.*, 2014). Yim *et al.* (2017) found that AR-based product presentations were superior to conventional web-based product presentations since they offer higher immersion, media novelty, and media enjoyment, and increase attitude toward medium and purchase intention. If a website utilizes AR, consumers become more curious about the products, tend to patronize the website, and eventually purchase the products (Beck and Crié, 2018). Beck and Crié (2018) validated their findings by conducting tests with two products (garments and eyeglasses) with both student and consumer samples. However, their study was an online study and not set in a laboratory environment where participants could use the same system and try-on the physical garment and accessory. To our knowledge, no studies empirically compared consumers' attitudes towards the product and purchase intentions between AR and real-world conditions. Therefore, we proposed the following hypothesis:

H2: AR virtual try-on will have a comparable effect to physical try-on in terms of users' (a) attitudes towards the apparel product and (b) purchase intentions.

A recent study by Kim *et al.* (2017) found that the use of AR is positively related to enhanced telepresence, which in turn contributes to attitude toward the technology, and purchase intention of products. In the study, researchers suggested that in comparison to virtual reality (VR)-based presentations (i.e., wearing sunglasses on a 3D virtual model), AR-based presentations (i.e., using a webcam to see themselves wearing sunglasses) were more likely to stimulate presence, thus leading to stronger purchase intentions. Other researchers also supported that telepresence increases attitudes towards products (Debbabi et al., 2013) and purchase intentions (Song et al., 2007; Watson et al., 2018). When comparing a VR interface to 2D photos and a video interface, Suh and Chang (2006) found that higher levels of telepresence (i.e., manipulated as VR in their study) increased positive attitudes toward the product, which was a computer desk. However, they did not find any direct association of purchase intentions with telepresence. Similar to previous studies which examined a variety of products from accessories to make-up in both VR and AR settings (Park and Yoo, 2020; Yim et al., 2017; Watson et al., 2018), telepresence in AR apparel virtual try-on may increase attitudes and purchase intentions toward the product. Thus, to understand the impact of telepresence on attitudes towards the apparel product and purchase intentions, we proposed the hypothesis presented below:

H3: When using AR virtual try-on, individuals who have a higher telepresence will have greater (a) attitudes towards the apparel product and (b) purchase intentions than those who have a lower telepresence.

Methods

Data were collected with a one-factor (i.e., garment) within-subject quasi-experimental study using repeated measures in two conditions: virtually trying-on condition using the AR technology vs. physically trying-on condition. Within-subject design was selected because it allowed researchers to remove subject-to-subject variation from the analysis of the relative effects of different treatments (Seltman, 2015). It is important to “consider the context” when deciding whether a between or within subject design should be selected (Charness, Gneezy and Kuhn, 2012, p.2). Therefore, to be able to create conditions similar to the real-world, and not conflict with the practice of online shopping (i.e., evaluating a garment on a website first and ordering it for physical try-on), we let the participants try on the same dress in AR first and did not reverse the order.

In this study, variance in participants’ body shapes and sizes is controlled with the within-subject research design. Each participant was asked to try on the virtual dress using the AR technology (Treatment 1); rate the perceived product performance, fit and size, attitudes and purchase intentions towards the dress; and then physically try on the same dress (Treatment 2) in a dressing room in the research lab after “ordering it online and receiving it via mail.” In a similar vein, after viewing the product (a computer table) in an online store by using three different viewing formats, Suh and Chang’s (2006) instructed their study participants to go to a separate room to view the physical product and compare it to the online product. After Treatment 2 in our study, participants answered the same set of questions that they did after Treatment 1. The two treatments in this study design were fundamentally different, as Treatment 1 required participants to evaluate the garment solely based on the visual images presented by the AR technology, whereas Treatment 2 allowed participants to evaluate the garment by seeing, touching, and wearing it. More details of the experiment procedure are discussed in the following sections.

Participants

Female college students age 18 and above were targeted as participants as they use the Internet for apparel shopping, are technology-savvy, and adopt new product visualization technologies easily (Yu *et al.*, 2012). Compared to men, women examine garments in more detail and tend to have more difficulty in selecting clothing items for themselves when shopping online (Hansen and Jensen, 2008). After receiving approval from the Institutional Review Board (IRB), undergraduate and graduate female participants were recruited via a large Midwestern university's mass-emailing service. A total of 87 participants from a variety of majors voluntarily participated in the study. Participants' mean age was 25.6 years old (SD = 6.08). The majority of the participants were European-American (n = 65, 74.7%), followed by Asian/Asian-American (n = 9, 10.3%), other (n = 6, 6.9%), Latino/Hispanic (n = 4, 4.6%), and African-American (n = 3, 3.4%). Most participants (89.7%) indicated that they had bought apparel online. To increase participation, each participant was offered a $5 gift card as incentive.

Stimulus

In this study, a dress was used to develop the treatments. For Treatment 1, the dress image was used in the AR technology for virtual try-on; for Treatment 2, the real dress was used for physical try-on. Based on their pilot study finding using a convenience sample of 52 female undergraduate students, Kim and Damhorst (2010) suggested dresses as the most frequently purchased garment type among students. Huang and Liu (2014) also found that dresses were among the top-three garments to be tried-on in AR; women spent the longest time on dresses when using AR for virtual try-ons. Considering computer monitor limitations, full-length dresses and pants are usually not easily seen with an online AR application. Also, full-length sleeves add an extra variable to control the believability of the AR simulation.

In order to select the stimulus, six dress images of various knee-length, short-sleeved/sleeveless dress styles were evaluated by five women in a pre-test. The pre-test examined the garment style's attractiveness, fashionability, and likeability, using a 7-point Likert-type scale adapted from Park (2009). The average ratings of the six dresses were as follows: 4.47 (short-sleeved fitted dress), 3.53 (sleeveless fitted dress), 5.33 (short-sleeved shift/A-line dress), 3.60 (sleeveless shift/A-line dress), 5.20 (sleeveless fit-and-flare dress), and 4.13 (short-sleeved fit-and-flare dress). Following suggestions from Kim and Lennon (2008) and Park (2009), the short-sleeved fit-and-flare dress with a neutral rating was chosen to limit the garment style's potential effect on the variables. The dress was purchased from a mass-retailer in sizes from XS (0-2) to XL (16-18). To eliminate the confounding effect of brand name, brand labels were removed from the dresses.

To create the dress image for Treatment 1, a photo of the dress in size medium was taken on an appropriate dress form. The dress form and background components were then erased in Adobe Photoshop. The final image was uploaded in PNG format to the AR developer's (Zugara) server (Figure 1). In the online AR application, the computer's webcam captured participants' body images, and the front-view of the stimulus was displayed on their body in 2D. Participants were able to adjust the size and placement of the AR dress by moving their hands in the air and "clicking" the control buttons shown on the screen without needing a mouse or a keyboard. This way, the computer screen became an interactive mirror without necessitating a high-tech kiosk (Figure 1).

Insert Figure 1 here

Since Treatment 2 was the real dress for physical try-on and should remain exactly the same as the Treatment 1 dress to avoid any variations other than the AR versus physical try-on conditions, the researchers intentionally made no adjustment to the dress. The researchers nonetheless made sure that all sizes of the dress were available in the lab for Treatment 2.

Experimental procedures

Participants were invited to our research laboratory and received instructions about the task and the procedures. Informed consent forms were filled out at the beginning. Participants were instructed to use an iMac on which the AR application website specifically developed for this study was available. To virtually try on the AR dress (Treatment 1), participants stood 4-5 steps in front of the computer screen with a built-in video camera, so they could see their bodies at least from head to calf. After the virtual try-on experience, participants were asked to complete an online questionnaire on a separate laptop. The questionnaire measured fit and size perceptions of the dress, product performance perceptions, telepresence, attitudes towards the dress, and purchase intentions. The respondents also indicated the size of the dress that would fit them. Next, participants physically tried on the real dress in the sizes they indicated previously (Treatment 2), then answered a second online questionnaire regarding the real dress with the same measurement instruments, except telepresence, as the previous questionnaire. We implemented "time-off" in two ways to minimize potential confounding effects of the within-subjects design: (1) after the first questionnaire, participants went to the changing room to try on the real dress and (2) we added three open-ended questions about participant reflections on AR (not included to the present study) between the questionnaires to make it hard to remember repeated questions between Treatment 1 and Treatment 2.

Survey instruments and data analysis procedures

Items used to assess dress fit involving thirteen areas (e.g., neck, busk, waist) except buttocks were adapted from the fit scales developed by Song and Ashdown (2012) using a 5-point scale that was anchored at *too loose/long/wide* (1), *excellent fit* (3), and *too tight/short/narrow* (5). Product performance in regards to both treatments was measured with the product performance risk scale adapted from Yu *et al.* (2012) using a 7-point Likert-type scale, which was anchored at *not sure at all* (1) and *very sure* (7). A question, "*How sure are you about the apparel product's attributes to perform satisfactorily to your needs?*", was asked to measure three dimensions (visual, tactile, and trial) at ten sub-dimensions (visual: style, fabric, color, details, coordination with other items; tactile: touch and feel, weight of garment; and trial: fit, comfort, and appearance on body) (Yu *et al.*, 2012). Telepresence was measured using the scale adapted from Song *et al.*'s (2007) five-item, 7-point Likert-type scale, which was anchored at *strongly disagree* (1) and *strongly agree* (7). The items asked if the application *"…lets me easily visualize what the real dress is like," "…gives me as much sensory information about the dresses as I would experience in a store," "…creates a product experience similar to the one I would have when shopping in a store," "…allows me to interact with the dresses as I would in the store,"* and *"…provides accurate sensory information about the dresses."*

Attitudes toward the AR and real dresses were evaluated using six items with a 7-point Likert-type scale from Holbrook and Batra (1987) and Bruner (1998) for the following question:

"Please tell us about your overall thoughts and feelings about the dress: The dress is..." The items were anchored at very dislikable (1)/very likeable (7), very unattractive (1)/very attractive (7), very bad (1)/very good (7), very unfavorable (1)/very favorable (7), very unpleasant (1)/very pleasant (7), very unappealing (1)/very appealing (7). Purchase intention was measured by a scale originated from MacKenzie *et al.* (1986) and used by Yu *et al.* (2012): very improbable (1)/very probable (7); very unlikely (1)/very likely (7); and very impossible (1)/very possible (7). The instrument was pilot tested with five students. Some phrases in the instructions and the questionnaire were further edited for clarity. Cronbach's *alpha*s of all scales were greater than 0.8. Table 1 shows the constructs, their items, and the reliability scores. To examine hypotheses, paired-sample t-tests and multivariate analysis of variance (MANOVA) were conducted in SPSS 26.

Insert Table 1 about here

Results

Results for H1

Finding the right size. No statistical difference was found between the virtually tried-on AR dress sizes (M = 2.69; SD = 1.16) and physically tried-on dress sizes (M = 2.65; SD = 1.23) ($t(86) = -1.75$; $p = .41$). Therefore Hypothesis 1a was supported. Table 2 shows the distribution of best-fitting dress sizes for AR (Treatment 1) and real (Treatment 2) dresses.

Insert Table 2 about here

Evaluating Fit. Before analyzing the overall fit of the dress using the product performance construct, fit was evaluated in more detail by looking at thirteen locations on both AR and real dresses. In general, all areas evaluated were perceived to be close to 3 (excellent fit). As shown in Table 3, there were no significant differences in fit at four areas (neck, shoulder width, sleeve opening, and volume/fullness in skirt) between AR and real dresses. However, results showed significant differences between these two conditions in nine areas out of thirteen. Participants perceived looser fit around bust ($\Delta M=.28$, $SD= 1.00$, $t(84) = 2.58$, $p < .05$) and wider shoulder ($\Delta M=.22$, $SD= .93$, $t(86) = 2.18$, $p < .05$) when virtually trying on the AR dress. However, areas such as waist ($\Delta M = -.39$, $SD = .97$, $t(86) =-3.76$, $p < .001$), abdomen ($\Delta M=-.26$, $SD=.88$, $t(83) =-2.37$, $p < .01$), and hip ($\Delta M=-.43$, $SD=.83$, $t(85) = -4.79$, $p < .001$) were perceived tighter when using AR. When using AR, lengths were perceived to be longer at the following areas: sleeve ($\Delta M= .29$, $SD= .85$, $t(85) = 3.16$, $p < .01$), torso ($\Delta M= .26$, $SD= .92$, $t(86) = 2.68$, $p < .01$), skirt ($\Delta M=.37$, $SD=.94$, $t(86) =-3.64$, $p < .001$), and overall dress length ($\Delta M=.42$, $SD=.76$, $t(84) =5.13$, $p < .001$). Therefore Hypothesis 1b was partially supported.

Insert Table 3 about here

Evaluating product performance. Out of ten attributes that investigated participants' perceived AR dress performance and real dress performance, nine items were found to be significantly different. Average ratings for the attributes related to tactile properties (i.e., touch and feel: $M=2.55$, weight: $M=2.81$) were lower than neutral (4) for the AR dress (see Table 1). When wearing the real dress, participants thought that nine dress attributes performed significantly better than when using AR: style ($\Delta M = .60$; $SD =1.69$; $t(86) = 3.30$; $p < .01$), fabric ($\Delta M = 2.01$; $SD = 2.15$; $t(85) = 8.68$; $p < .001$), coordination with other items ($\Delta M = .48$; $SD = 1.45$; $t(85) = 3.04$; $p < .001$), details ($\Delta M = .96$; $SD = 1.64$; $t(86) = 5.50$; $p < .001$), touch and feel ($\Delta M = 3.34$; $SD = 2.17$; $t(86) = 14.32$; $p < .001$), weight ($\Delta M = 3.21$; $SD = 2.05$; $t(84) = 14.42$; $p < .001$), fit ($\Delta M = 1.16$; $SD = 1.85$; $t(85) = 5.82$; $p < .001$), comfort ($\Delta M = 2.53$; $SD = 2.17$; $t(84) = 10.75$; $p < .001$), and appearance on the body ($\Delta M = .46$; $SD = 2.09$; $t(85) = 2.06$; $p < .05$). Color (ΔM

=.41; SD = 1.93; $t(85) = 1.12$; $p > .05$) was not significantly different between the two conditions (Table 4). Therefore Hypothesis 1c was partially supported.

Insert Table 4 about here

Results for H2

A paired-sample t-test was conducted to test Hypotheses 2a (H2a) and 2b (H2b). Attitudes towards both AR and real dress were favorable and above 5. Purchase intentions were moderately positive in both conditions as well (Table 1). Participants had significantly more favorable attitudes towards the real dress (M = 5.60, SD = 1.14) than the AR dress (M = 5.25, SD = 1.00) (ΔM = .35, SD = 1.15, $t(85) = 2.62$, $p < .05$). Participants indicated greater purchase intentions during physical try-on (M = 4.74, SD = 1.71) as compared to AR try-on (M = 4.27, SD = 1.70) (ΔM = .47, SD = 1.94, $t(85)=2.32$, $p < .05$). Thus, H2a and H2b were not supported.

Results for H3

In order to examine Hypothesis 3, participants were split into two groups based on the mean value of telepresence (M=3.70). Participants who indicated telepresence 3.70 and higher on average were assigned to the high telepresence group (n=39), whereas participants who had telepresence level lower than 3.70 were placed in the low telepresence group (n=48). Results of MANOVA showed that the high telepresence group tended to have more positive attitudes ($M_{\text{Low Telepresence}}$= 5.04 (SD = .14), $M_{\text{High Telepresence}}$=5.50 (SD =.16)) and greater purchase intentions to the apparel product when using AR ($M_{\text{Low Telepresence}}$= 3.88 (SD = .24), $M_{\text{High Telepresence}}$=4.77 (SD =.27)) than the low telepresence group [$F_{(1, 83)} = 3.15$; $p <.05$, partial $\eta 2= .071$]. Thus, Hypothesis 3a and 3b were supported.

Discussion

In this present study, we investigated if AR can help online apparel shoppers order the right size, obtain clues about fit and product performance by judging visual clues, and determine if virtually trying on an AR garment is the same as physically trying it on in regard to attitudes towards the garment and purchase intentions. Additionally, we examined how high and low telepresence levels of the participants in the AR condition impact their attitudes and purchase intentions. Understanding how online AR technologies affect consumers' perceptions of garments can help brands develop new ways to reduce consumers' regret caused by post-purchase expectation disconfirmation. In our study, the majority of the participants were able to select their sizes correctly and did not need to try on a different size once they "received" the garment "via mail" after "ordering it online." Narvar's (2017) survey shows that online apparel shoppers make bracket purchases, which means buying multiple versions of an item (size-, color- and style-wise) to see which they prefer, with the intention of returning the rest. In this regard, using AR would be very beneficial for retailers to implement as it gives shoppers more confidence in the sizes they want to try at home and reduces bracket purchases that increase re-shelving and shipping costs. Implications also include using this technology in a physical store environment to help shoppers quickly sort through styles to find what they like.

In regard to perceiving fit, our study found that participants were able to approximate how garment parts would fit (loose, tight, or right) when using an AR application. Therefore, our results imply that AR virtual try-on can give shoppers visual clues on the garment fit. However, the type of AR technology (3D overlay vs. 2D overlay), interactivity speed, and quality of the AR images impacts the level of visual information (realistic vs. graphic) that shoppers receive (Yim *et al.*, 2017). In our study, when compared to the real dress, fit of the AR dress was perceived to be significantly looser at the bust and tighter at the waist, abdomen, and hip. The discrepancies found around the waist, abdomen, and hip are considered plausible because the AR dress was a superimposed, static 2D image on the body, not stretching at these areas. Our finding on the fit perception at bust was unexpected. This result may have arisen from a possible difference between the bust measurements of the dress form, which was used to create the AR dress stimuli, and study participants. Moreover, lengths of sleeve, torso, skirt, and overall dress were perceived to be significantly longer in AR. Holding a garment up to oneself and assessing its length may be different than wearing it. After wearing the garment, the third dimension (depth) adjusts the garment length on the body and the garment becomes shorter than its flat form against the body.

Although in our study only one type of stimulus (dress) was used, the findings may inform improvement of AR applications to help consumers evaluate fit. For example, garment pictures may be improved by taking several pictures of the same product depending on different body types or sizes (petite, regular, tall, and plus) to reduce the discrepancy. The images can be adapted to each user's body shape, to the extent that the materials' elasticity allows. While retailers do not have much control over how AR technology improves, the findings can help inform consumers of possible discrepancies, allowing for more accurate decisions regarding fit.

Almost all of the product-performance-related items, except color, were perceived significantly different in two conditions. Attributes such as style, fabric, coordination with other items, details, touch and feel, weight, overall fit, comfort, and appearance on body were perceived to perform better for the real dress. The average ratings for tactile attributes (e.g., touch and feel, comfort, and weight) were closer to the unsatisfactory side of the scale when using AR. In AR, users cannot account for tactile attributes such as touch and feel, comfort and weight. Nonetheless, results related to specific visual characteristics (i.e., style, detail, and coordination with other items), were above the neutral level when using AR, showing that AR visuals were satisfactory to help participants understand these attributes when shopping online.

The findings showed that physical try-on condition affected consumers to have higher attitudes and purchase intentions compared to AR try-on condition. An explanation could be that consumers still prefer and make decisions based on the actual tactile experience they gained from physical try-on. However, it does not mean that AR is useless to consumers. As the findings from H1 indicated, AR does provide good visual information that can increase consumers' attitudes and purchase intentions. Furthermore, participants with higher telepresence level were found to have more positive attitudes towards the dress and greater purchase intentions when using AR as compared to the participants with low telepresence level. This finding adds to the existing literature (Debbabi et al. 2013; Kim et al, 2017; Suh and Chang, 2006) of how varying levels of telepresence affect attitudes towards the product and purchase intentions from the apparel field's point-of–view.

Conclusion

In the present study, the S-O-R model was used as a theoretical framework to investigate how AR products, most specifically a dress, and AR try-on would be perceived by consumers in comparison to physical interaction with the dress. For this purpose, we used an online shopping scenario that allowed our participants to experience the AR product, "order it" to see the physical dress, and decide if they want to keep it after physical try-on (i.e., purchase intention of the real dress). In addition to contributing to the academic field of AR product presentation in online shopping, our findings offer several implications for research and society/practice. Theoretical contributions of this research imply that although physical try-on plays an important role in apparel purchase decisions, AR stimulus can provide information that helps consumers make accurate decisions particularly regarding apparel sizes and visual characteristics when shopping online. Therefore AR can supplement, rather than replace, the physical try-on experience. Attitudes towards the dress and intentions to purchase the dress when using the AR technology were above the mid-point, and close to the attitudes and intentions measured in the physical try-on condition. Additionally, participants with higher telepresence levels were likely to have higher attitudes and purchase intentions as compared to the participants with low telepresence. These findings suggest that AR can be instrumental in introducing a certain style, building positive attitudes towards products, and driving sales when the consumers perceive a certain level of telepresence.

Although adopting AR to provide more information about the product on an e-commerce environment would be an expensive investment (Plotkina and Saurel, 2019), our findings imply that retailers can benefit from using AR technology to increase consumer interest in their products. Retailers need to understand the potentials of AR technologies and work with technology developers to push the limits to enhance shopper experiences. As suggested by Pantano *et al.* (2017), fashion retailers who want to implement AR systems should be aware of the recent progresses as well as drawbacks in technology, taking part in the innovation process rather than passively adopting the offered technology. AR technology is an untapped area in apparel, and its potential in conveying reliable information when shopping online needs to be examined more closely.

Some limitations of the present study must be addressed. First, the use of a student population reduces the generalizability of the study findings. Additionally, the vast majority of these women were in the XS-M category with very few women in the larger sizes. The product chosen for this experiment is another limitation. As Kim and Lennon (2008) indicated, when a single stimulus is used, the results cannot be generalized to other stimuli. Different garment types in varying silhouettes and fit must be considered for further study. Future studies should apply our methodology to other product categories and compare the results. Technology accounts for a third limitation. The AR garments were 2D and did not wrap around the body. Lu and Smith (2007) mentioned that AR system rendering should be improved to merge digital and real environments in a realistic way. This would improve vividness, i.e., “the ability of a technology to produce a sensorially rich mediated environment” (Steuer 1992, p. 80). As Suh and Chang (2006) suggested, focus should be on improving IIT interfaces to generate higher telepresence levels, so that consumers’ perceptions of products in online stores can be improved. Plotkina and Saurel (2019) argue that AR-based tools for trying on garments virtually are not “sufficiently technologically advanced” yet. Their study compared a mobile application with AR try-on to a mobile commerce interface that presented fashion models similar to the consumers. Plotkina and Saurel (2019) found that their female participants preferred traditional pictures. The present study used the AR provider’s server; therefore, fiber, fabric information, and price were not included on the website. Participants did not get clues on whether the fabric would stretch when wearing the dress, or if the dress was affordable. Written explanations would encompass the limitations and overcome picture-related misconceptions. As Kim and Lennon (2008) suggested, detailed verbal descriptions are important to enhance consumer understanding of the product and positively influence their purchase decisions. Additionally, collecting information from males would be a good idea, as they have different preferences and were reported to be less confident when selecting clothes without advice from a knowledgeable person (Hansen and Jensen, 2009; O’Cass, 2004). The present study examined the influence of AR, which was developed by a specific technology provider, on telepresence based on the S-O-R model. Future studies should consider other providers as well as advancing AR functions, and using additional theoretical models to compare the effects of different AR try-on conditions on telepresence.

Another limitation was the experimental design. Because a within-subject experimental design was selected, with a possible carry-over effect, it is possible that attitudes and purchase intentions were higher in the physical try-on condition due to the participants' learning of the product, which might have been reinforced by experiencing the same product twice, first virtually and second physically. Future research should look at conducting a between-subject experiential design. Future studies should also investigate factors such as visual imagery on AR fitting experience to better differentiate its competitive advantage as compared to virtual try-on based on parametric models. Finally, future researchers should examine the perceived value of AR fitting systems and their influence on consumer experience. Although AR fitting has limitations on providing accurate fit information, based on our study, the unique interactive features may contribute to consumers' perceived value of the shopping experience.

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Figure 1. Representation of the AR interface showing the controls and the dress stimulus

Table 1.

The Descriptive Statistics of Survey Instruments

Constructs	AR dress			Real dress		
	n	M (SD)	α	n	M (SD)	α
Product performance						
Style	87	5.10 (1.39)	N/A	87	5.70 (1.37)	N/A
Fabric	86	3.73 (1.90)	N/A	86	5.74 (1.24)	N/A
Color	86	4.79 (1.50)	N/A	86	5.20 (1.59)	N/A
Coordination with other items	86	5.22 (1.50)	N/A	86	5.70 (1.23)	N/A
Details	87	4.37 (1.41)	N/A	87	5.33 (1.38)	N/A
Touch and feel	87	2.55 (1.84)	N/A	87	5.89 (1.09)	N/A
Weight of garment	85	2.81 (1.91)	N/A	85	6.02 (.99)	N/A
Overall Fit	86	4.20 (1.71)	N/A	86	5.36 (1.59)	N/A
Comfort	85	3.38 (2.01)	N/A	85	5.91 (1.14)	N/A
Appearance on the body	86	4.63 (1.66)	N/A	86	5.09 (1.71)	N/A
Telepresence	86	3.70 (1.25)	.88		N/A	
Attitude towards the dress	86	5.25 (1.00)	.94	86	5.60 (1.14)	.96
Purchase Intention	86	4.27 (1.70)	.96	86	4.74 (1.71)	.96

Notes. M = mean, SD = standard deviation, α = Cronbach'*s alpha*

7-point Likert-type scales were used to measure the constructs/ items

Table 2.

Distribution of AR (virtual try-on) and Real (physical try-on) Dress Sizes

		Which dress size fit you best?					
		XS	S	M	L	XL	XXL
What size do you think you should wear for this dress?	XS	11	0	0	0	0	0
	S	2	27	0	0	0	0
	M	0	4	24	4	0	0
	L	0	0	2	5	0	0
	XL	0	0	0	0	3	1
	XXL	0	0	0	0	0	3

Table 3.

Fit Comparisons at Thirteen Areas

Fit location	Real dress fit M (SD)	AR dress fit M (SD)	ΔM (SD)	*df*	*t*	*AR dress fits…than real dress*
Neck	2.44 (.54)	2.48 (.65)	-.04 (.60)	85	-.54	-
Bust	2.76 (.68)	2.48 (.85)	.28 (1.00)	84	2.58*	Looser
Waist	3.02 (.65)	3.41 (1.00)	-.39 (.97)	86	-3.76***	Tighter
Abdomen	3.14 (.60)	3.40 (.78)	-.26 (.88)	83	-2.73**	Tighter
Hip	2.98 (.34)	3.41 (.77)	-.43 (.83)	85	-4.79***	Tighter
Armhole	3.34 (.61)	3.11 (.89)	.23 (1.05)	83	1.86	-
Shoulder width	2.95 (.61)	2.73 (.86)	.22 (.93)	86	2.18*	Wider
Sleeve opening	3.25 (.51)	3.06 (.76)	.19 (.88)	85	1.97	-
Volume/fullness in skirt	3.06 (.47)	3.06 (.56)	.00 (.68)	86	.00	-
Sleeve length	3.27 (.50)	2.98 (.76)	.29 (.85)	85	3.16**	Longer
Torso length	3.20 (.63)	2.94 (.85)	.26 (.92)	86	2.68**	Longer
Skirt length	3.17 (.77)	2.80 (.73)	.37 (.94)	86	3.64***	Longer
Overall dress length	3.14 (.64)	2.72 (.67)	.42 (.76)	84	5.13***	Longer

Notes. ΔM =Real dress fit-AR dress fit.

A 5-point scale, anchored at *too loose/long/wide* (1), *excellent fit* (3), and *too tight/short/narrow* (5), was used to measure the items.

p* < .05. ** *p* < .01. * *p* < .001.

Table 4.

Product Performance Comparison of Ten Apparel Attributes

	ΔM	SD	*df*	*t*
Style	.60	1.69	86	3.30**
Fabric	2.01	2.15	85	8.68***
Color	.41	1.93	85	1.12
Coordination with other items	.48	1.45	85	3.04**
Details	.96	1.64	86	5.50***
Touch and feel	3.34	2.17	86	14.32***
Weight of garment	3.21	2.05	84	14.42***
Overall Fit	1.16	1.85	85	5.82***
Comfort	2.53	2.17	84	10.75***
Appearance on the body	.46	2.09	85	2.06*

Note. ΔM =Real dress performance-AR dress performance

*$p < .05$. **$p < .01$. ***$p < .001$.